1.5 Direct and Indirect Band Gap Semiconductors

1.5.1 Direct Band Gap Semiconductors

The band gap represents the minimum energy difference between the top of the valence band and the bottom of the conduction band.However, the top of the valence band and the bottom of the conduction band are not generally at the same value of the electron momentum. In a direct band gap semiconductor, the top of the valence band and the bottom of the conduction band occur at the same value of momentum, as in the schematic below.

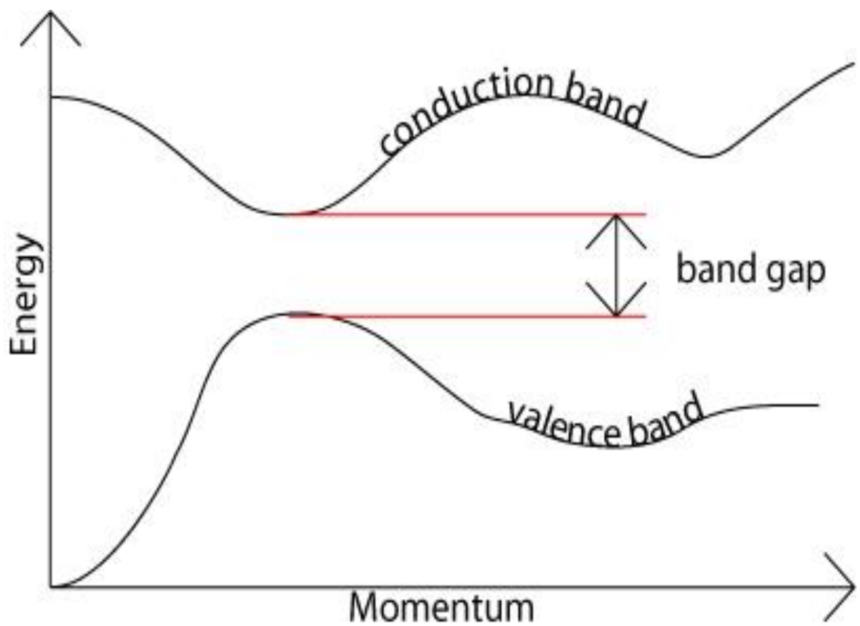

Fig. 1.24 Direct Band Gap Semiconductors

1.5.2 Indirect band gap semiconductor

In an **indirect band gap semiconductor**, the maximum energy of the valence band occurs at a different value of momentum to the minimum in the conduction band energy:

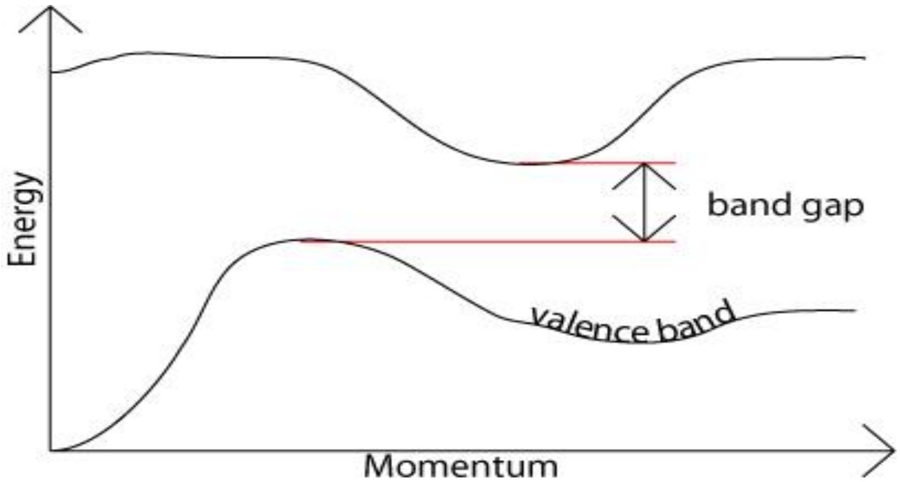

Fig. 1.25 Indirect Band Gap Semiconductors

1.5.3 Differences

The difference between the two is most important in optical devices. As has been mentioned in the section charge carriers in semiconductors, a photon can provide the energy to produce an electron-hole pair.

Each photon of energy E has momentum $p = E / c$, where c is the velocity of light. An optical photon has an energy of the order of 10^{-19} J, and, since $c = 3 \times 10^{8}$ ms^{-1}, a typical photon has a very small amount of momentum.

A photon of energy E_g, where E_g is the band gap energy, can produce an electron-hole pair in a direct band gap semiconductor quite easily, because the electron does not need to be given very much momentum. However, an electron must also undergo a significant change in its momentum for a photon of energy E_g to produce an electron-hole pair in an indirect band gap semiconductor. This is possible, but it requires such an electron to interact not only with the photon to gain energy, but also with a lattice vibration called a phonon in order to either gain or lose momentum.

The indirect process proceeds at a much slower rate, as it requires three entities to intersect in order to proceed: an electron, a photon and a phonon. This is analogous to chemical reactions, where, in a particular reaction step, a reaction between two molecules will proceed at a much greater rate than a process which involves three molecules.

The same principle applies to recombination of electrons and holes to produce photons. The recombination process is much more efficient for a direct band gap semiconductor than for an indirect band gap semiconductor, where the process must be mediated by a phonon.

As a result of such considerations, gallium arsenide and other direct band gap semiconductors are used to make optical devices such as LEDs and semiconductor lasers, whereas silicon, which is an indirect band gap semiconductor, is not. The table in the next section lists a number of different semiconducting compounds and their band gaps, and it also specifies whether their band gaps are direct or indirect.

1.5.4 What are Drift Current and Diffusion Current: Their Differences?

In a semiconductor, the majority and minority charge carriers will exit in p-type or n-type. Because both the types of semiconductors will present over a single crystal at the center so that PN-junction can be formed. When the doping of this junction diode is done non-uniformly then charge carriers movement will be an exit from high to low concentration which leads to the recombination of carriers as well as to the diffusion process. There is an additional method is also occurs based on the applied electric field namely drift current. This article discusses the main differences between drift current and diffusion current.

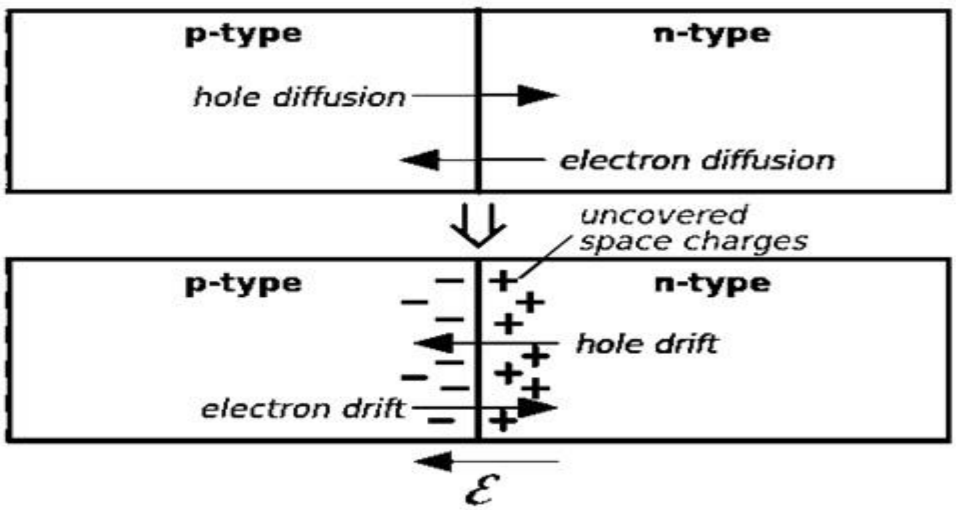

Fig.1.26 Drift Current and Diffusion Current

1.5.4.1 What is a Drift Current?

Drift current can be defined as the charge carrier's moves in a semiconductor because of the electric field. There are two kinds of charge carriers in a semiconductor like holes and electrons. Once the voltage is applied to a semiconductor, then electrons move toward the +Ve terminal of a battery whereas the holes travel toward the –Ve terminal of a battery.

Here, holes are positively charged carriers whereas the electrons are negatively charged carriers. Therefore, the electrons attract by the +Ve terminal of a battery whereas the holes attract by the -Ve terminal of a battery.

1.5.4.2 What is Diffusion Current?

The diffusion current can be defined as the flow of charge carriers within a semiconductor travels from a higher concentration region to a lower concentration region. A higher concentration region is nothing but where the number of electrons present in the semiconductor.

Similarly, a lower concentration region is where the less number of electrons present in the semiconductor. The process of diffusion mainly occurs when a semiconductor is doped non-uniformly.

In an N-type semiconductor, when it is doped non-uniformly then a higher concentration region can be formed at the left side whereas the lower concentration region can be formed at the right side. The electrons in the higher concentration region are more in the semiconductor so they will experience a repulsive force from each other

1.5.4.3 Difference between Drift Current and Diffusion Currents

The difference between drift current and diffusion current are:-

Drift Current	Diffusion Current
The movement of charge carriers is because of the applied electric field is known as drift current.	The diffusion current can be occurred because of the diffusion in charge carriers.
It requires electrical energy for the process of drift current.	Some amount of external energy is enough for the process of diffusion current.
This current obeys Ohm’s Law.	This current obeys Fick’s Law.
The direction of charge carriers in the semiconductor is reverse to each other.	For charge carriers, the densities of diffusion are reverse in symbol to each other.
The direction of the drift current, as well as the electric field, will be the same.	The direction of this current can be decided by the concentration of the carrier slope.
It depends on the permittivity	It is independent of permittivity
The direction of this current mainly depends on the polarity of the applied electric field.	The direction of this current mainly depends on the charge within the concentrations of carrier